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(54) **FUEL INJECTOR**

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F02M 51/06	(2006.01)
F02M 61/04	(2006.01)
F02M 61/18	(2006.01)

(52) **U.S. Cl.**

CPC ***F02M 51/061*** (2013.01); ***F02M 61/04*** (2013.01); ***F02M 61/18*** (2013.01)

(58) **Field of Classification Search**

CPC F02M 51/0603; F02M 51/005; F02M 51/0625; F02M 61/10; F02M 61/168; F02M 61/188

USPC 239/585.1, 585.3, 585.4, 585.5, 533.12

See application file for complete search history.

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(57) **ABSTRACT**

A fuel injector has a cylindrical nozzle body, a nozzle needle, a pressure chamber and an injection passage. The injection passage includes a first hole and a second hole. A minimum vertical distance between an outer periphery of a first nozzle hole outlet and a contact point relative to an axial center line of the first hole is defined as a vertical distance R. A minimum axial distance between the first nozzle hole outlet and the contact point relative to an axial center line of the first hole is defined as an axial distance L. An angle between the axial center line of the first nozzle hole and the outer periphery line of the fuel spray is defined as an injection angle θ. The vertical distance R, the axial distance L and the injection angle θ satisfy a formula: $R/(L \times \tan\theta) > 6.0$.

7 Claims, 5 Drawing Sheets

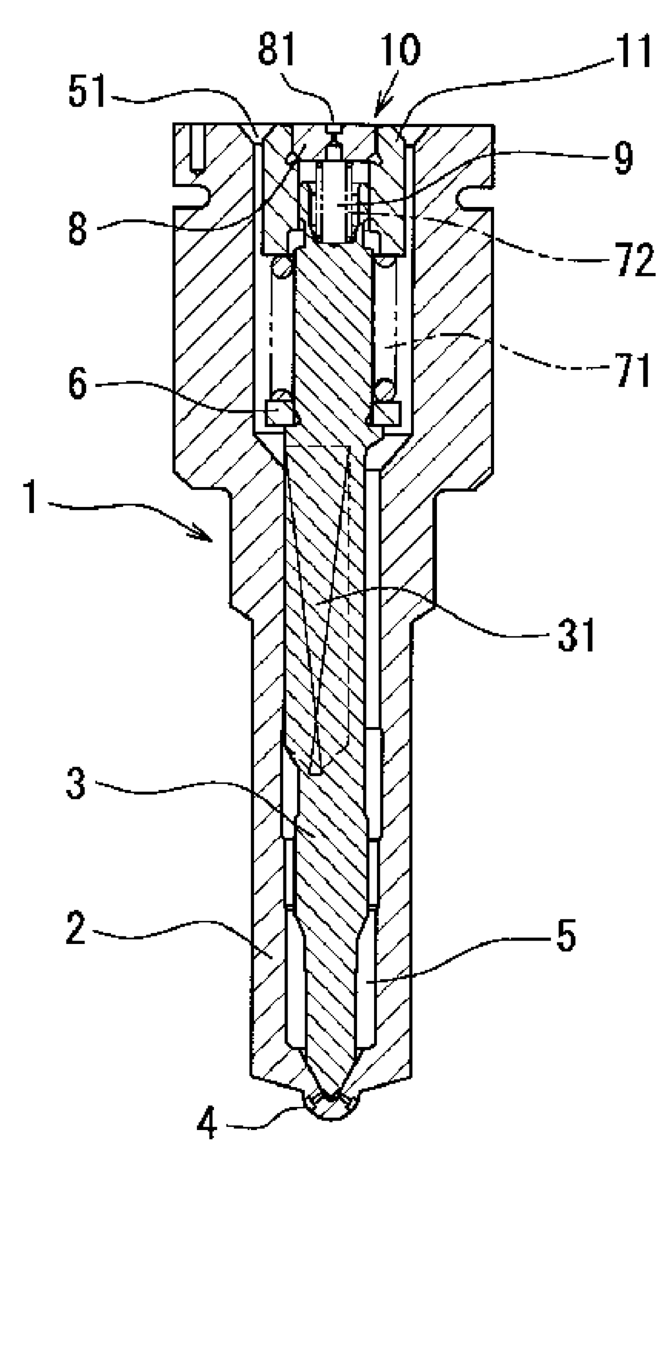


FIG. 1

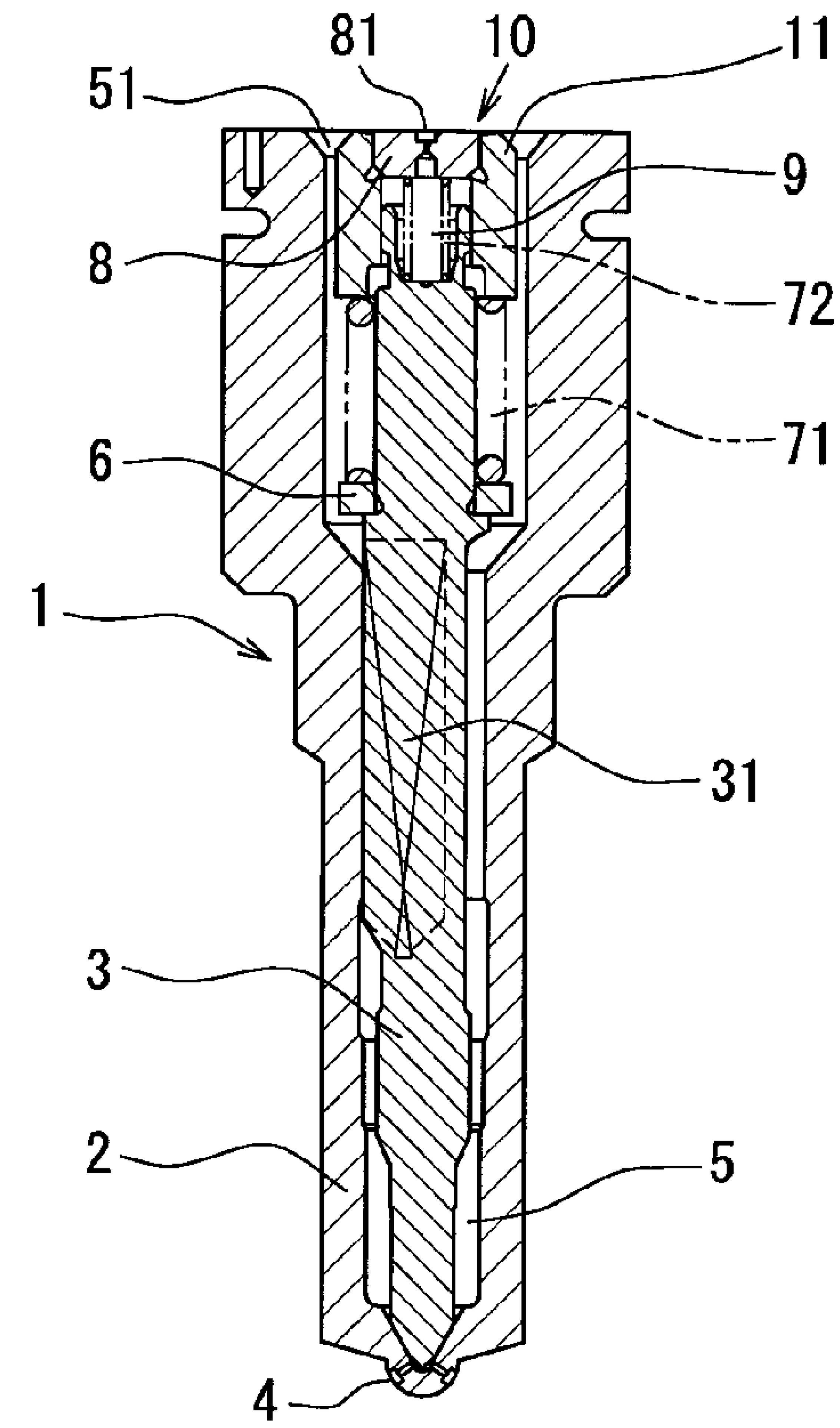


FIG. 2

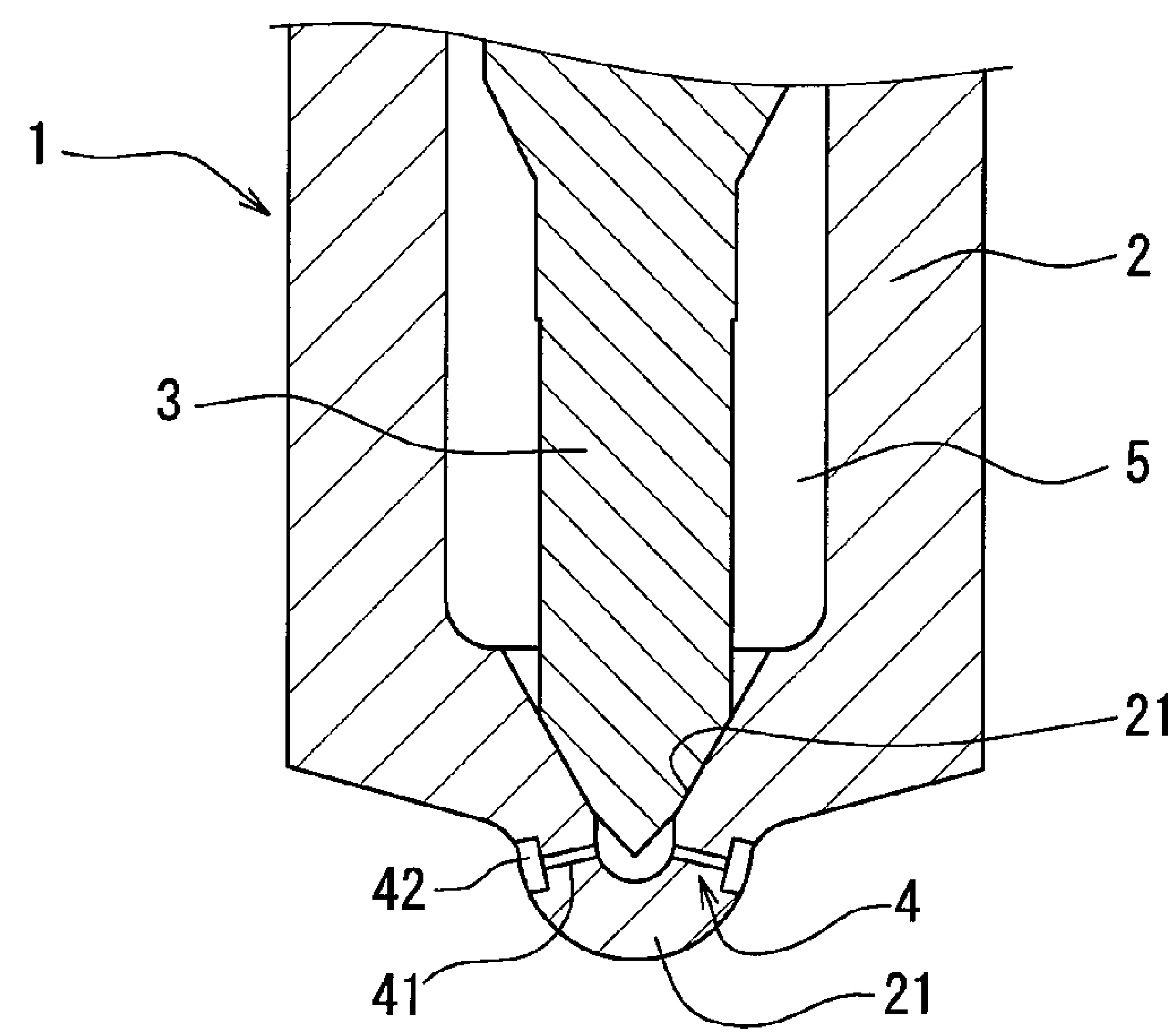


FIG. 3

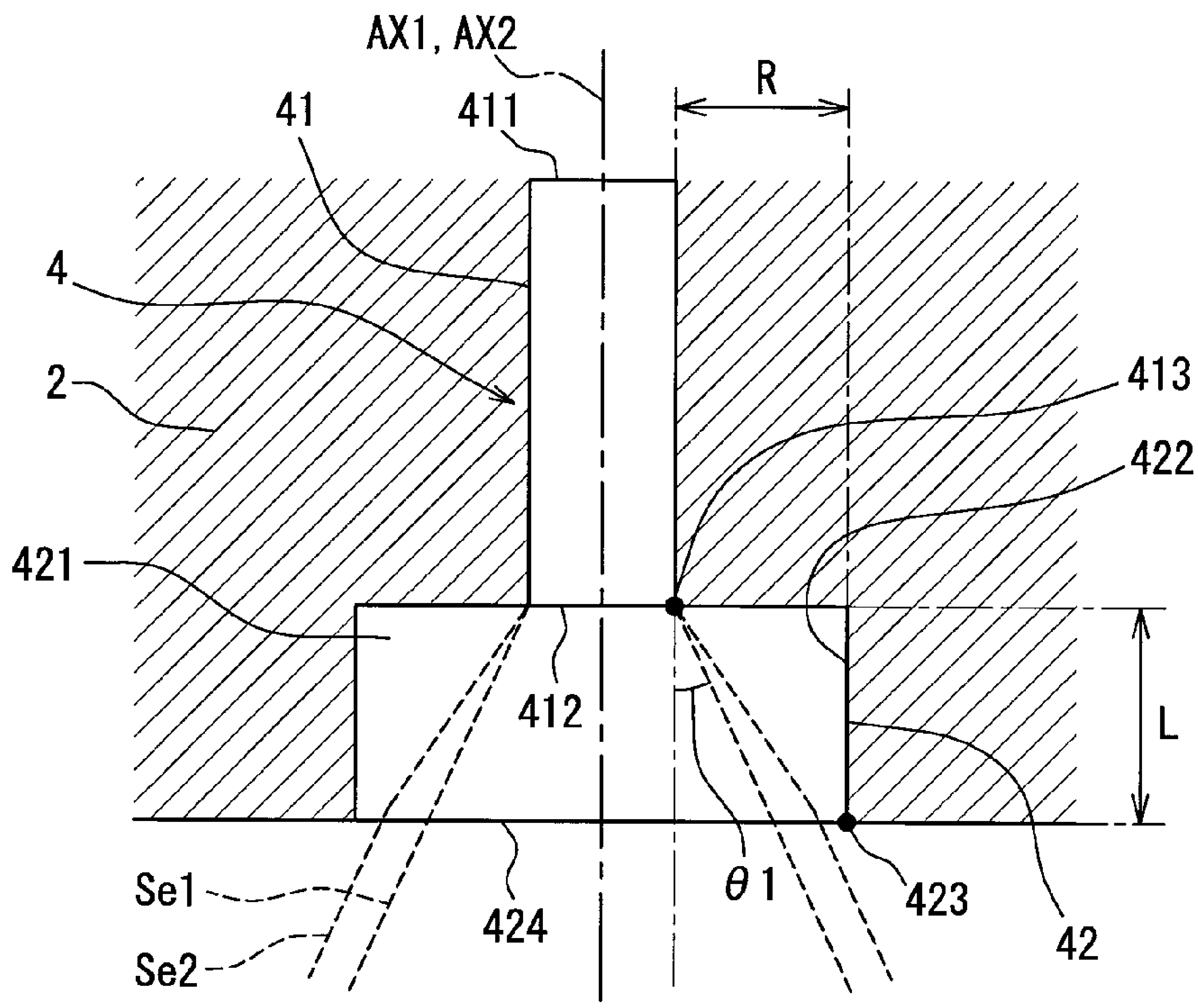


FIG. 4

			Test1		Test2		Test3		Test4	
INSECTOR	R (mm)	L (mm)	θ	X	θ	X	θ	X	θ	X
A	0.2	0.2	5.6	6.0	7.5	7.6	5.3	10.8	6.2	10.8
B	0.19	0.25	9.8	4.7	8.2	5.3	5.9	7.4	7.3	7.4
C	0.2	0.15	8.3	9.1	6.7	12.2	6.2	13.1	7.2	13.1
D	0.2	0.1	6.5	18.3	6.4	20.0	5.4	23.7	5.9	23.7
E	0.22	0.2	4.3	15.1	3.1	21.2	18.9	3.3	-	-
F	0.15	0.2	3.5	12.2	6.4	6.7	19.1	2.2	-	-
G	0.22	0.3	8.9	4.6	9.1	4.5	8.9	4.6	8.1	5.0
H	0.21	0.3	9.0	4.4	9.3	4.3	12.7	3.1	8.5	4.7

FIG. 5

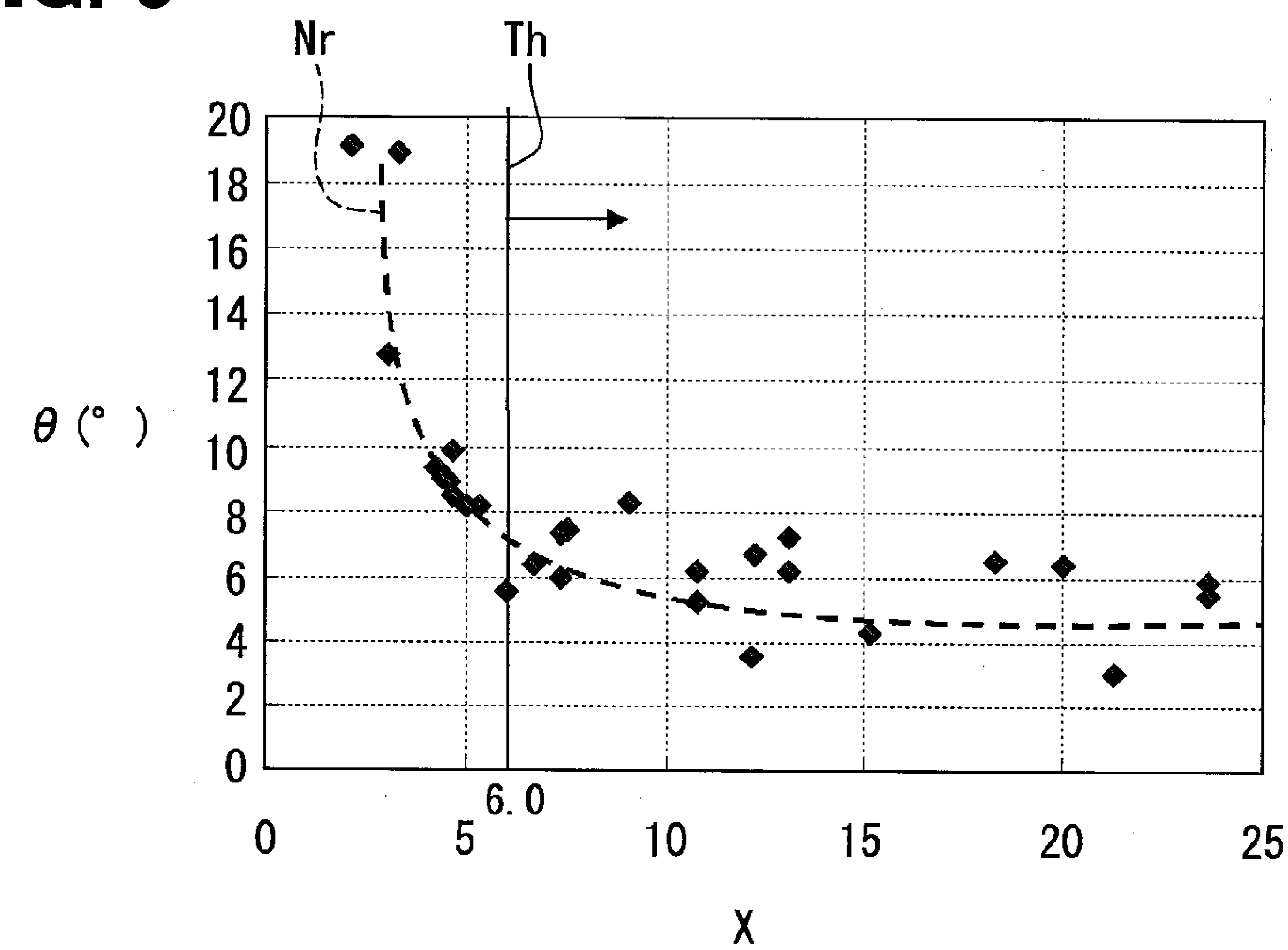

Nr
Th
20
18
16
14
12
10
8
6
4
2
0
θ (°)
6.0
0
5
10
15
20
25
X

FIG. 6

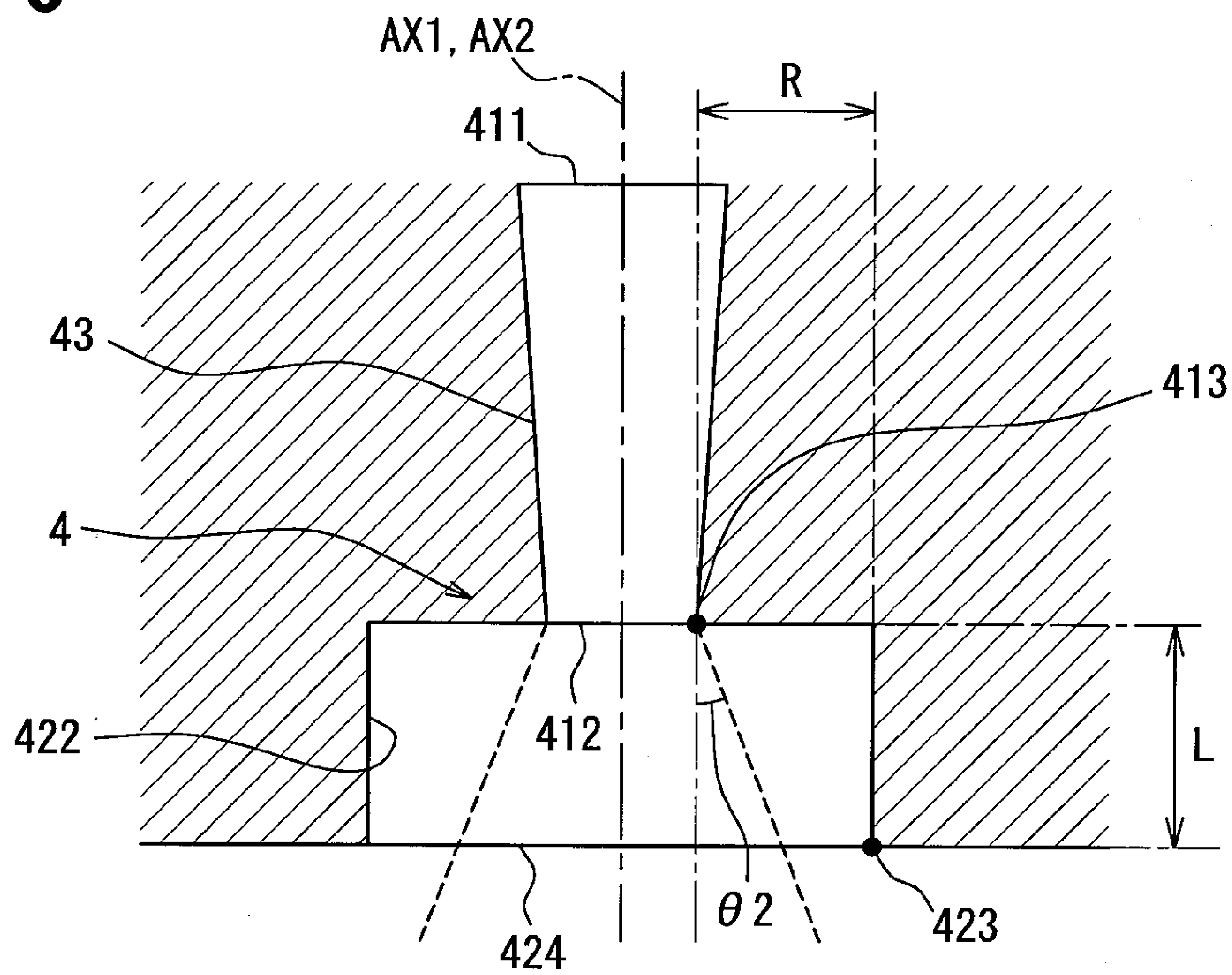

AX1, AX2
R
411
43
413
4
422
412
L
θ2
424
423

FIG. 7

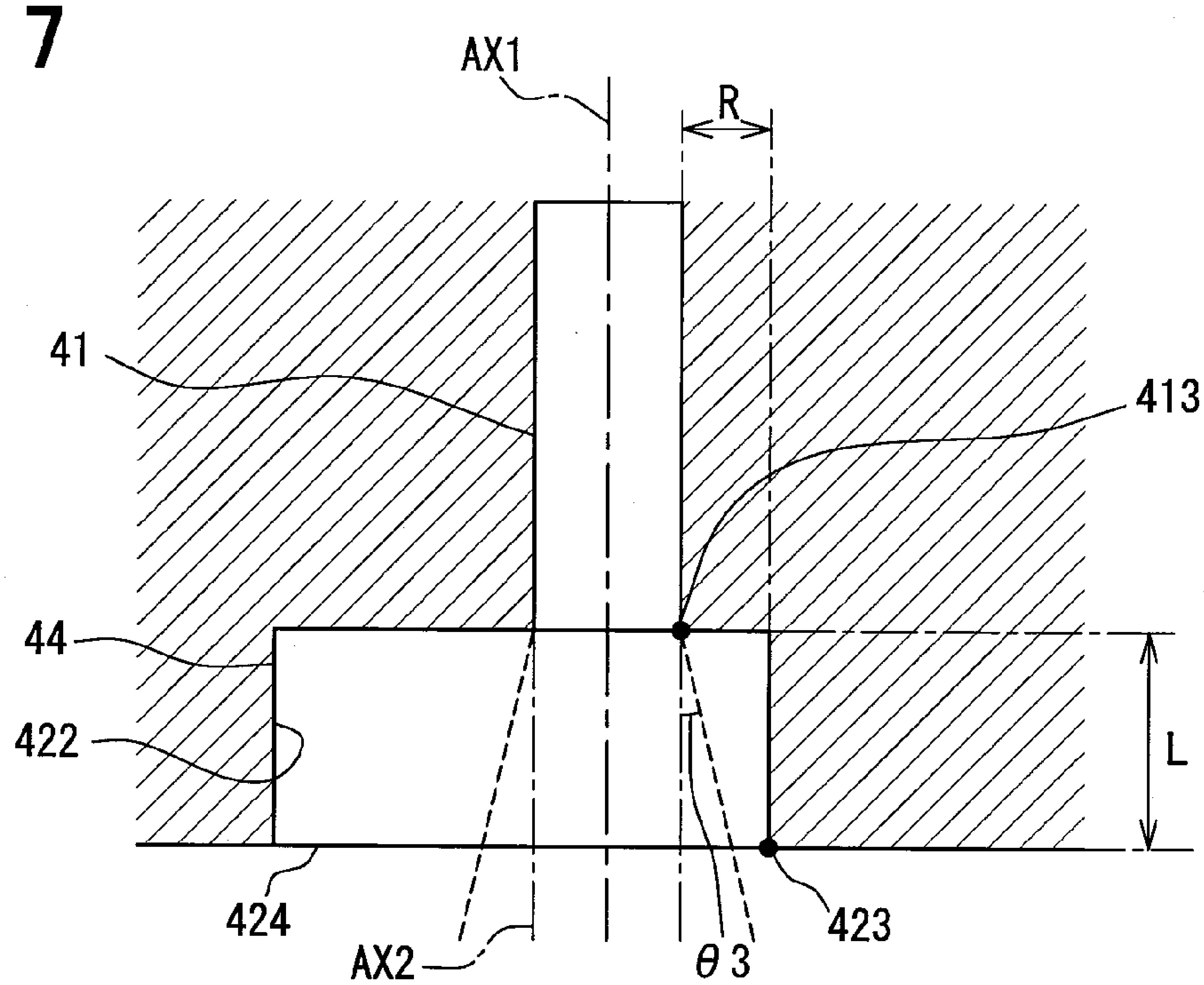

AX1
R
41
413
44
422
L
424
AX2
θ3
423

FIG. 8

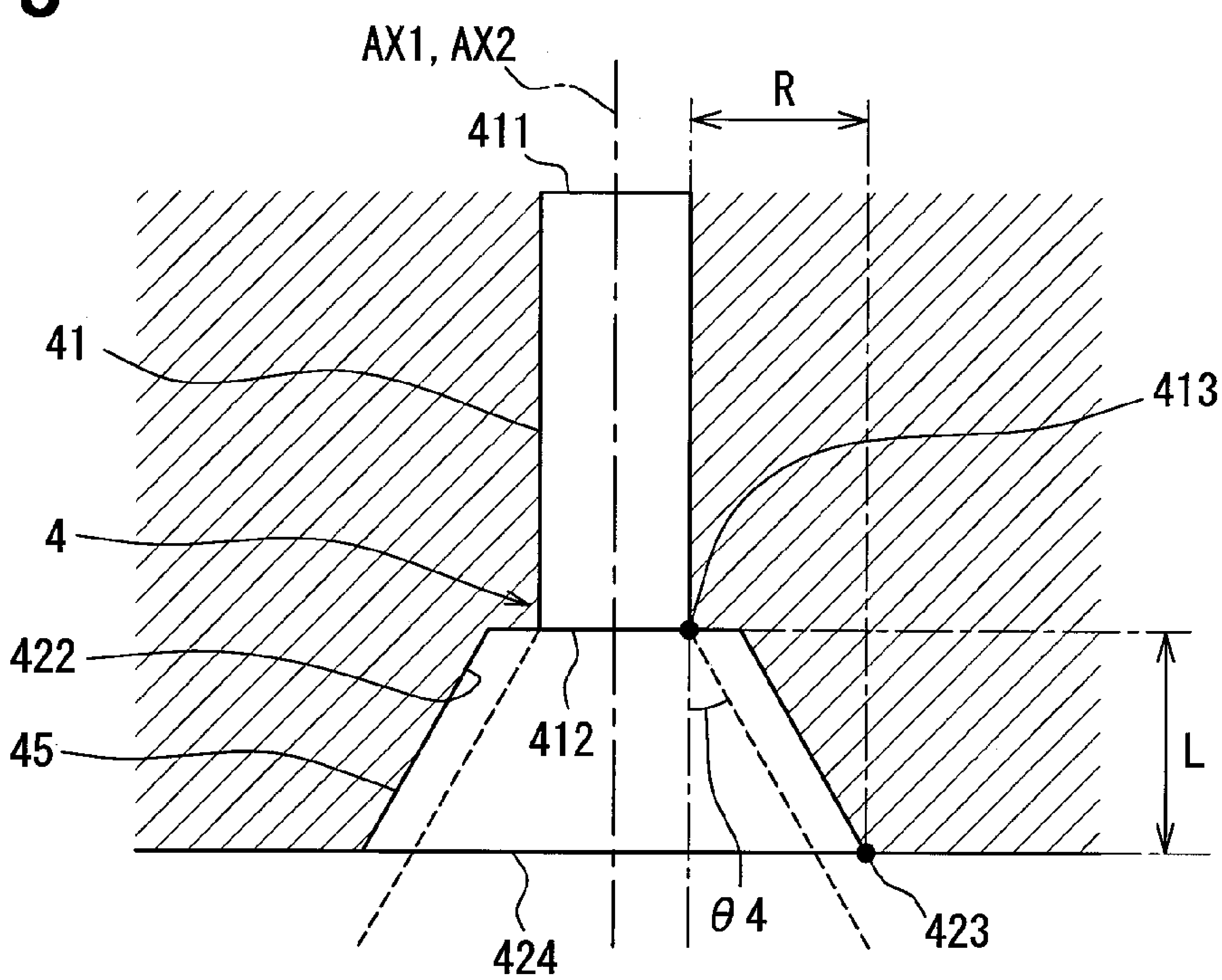
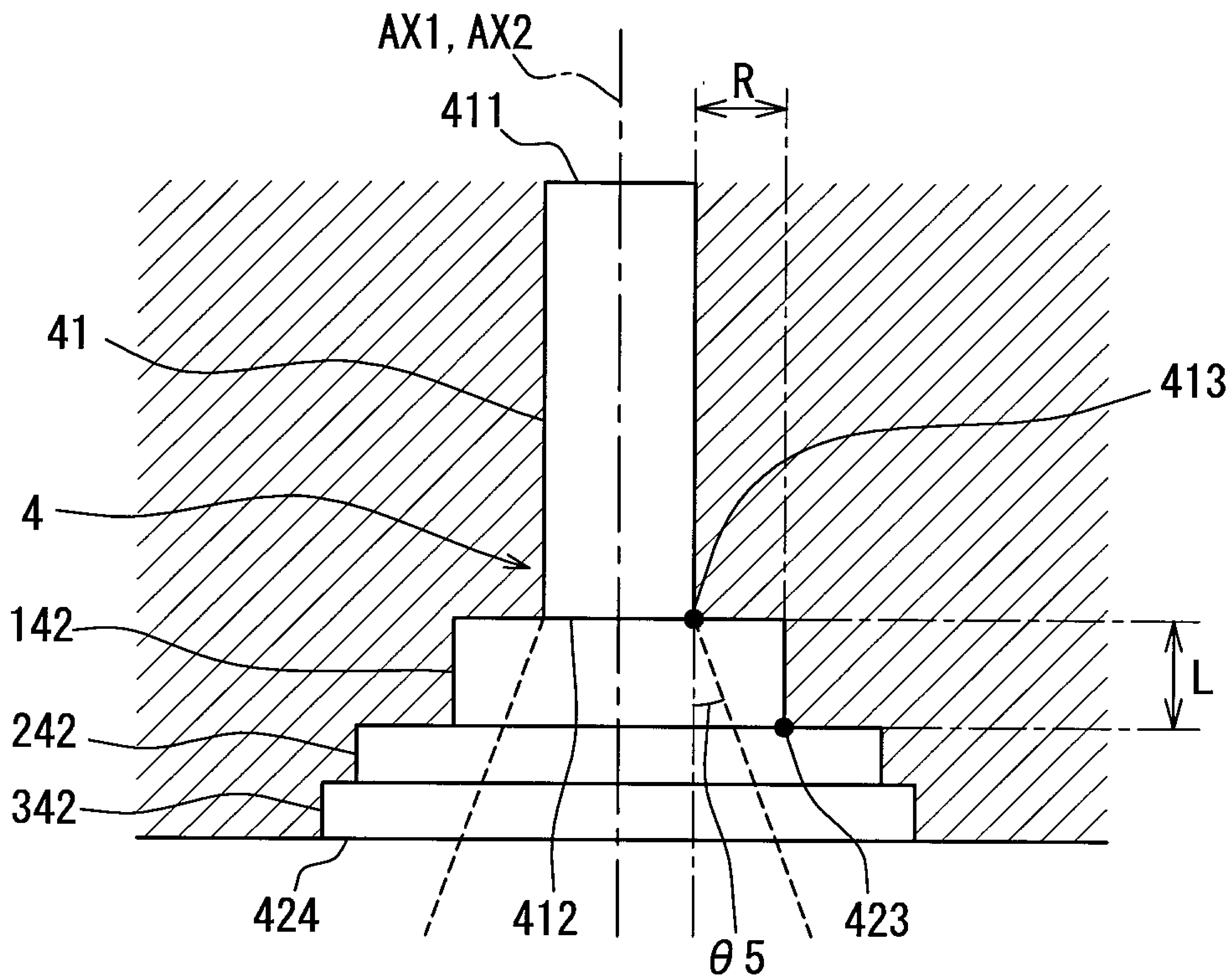

AX1, AX2
R
411
41
413
4
422
412
45
L
424
θ4
423

FIG. 9



FUEL INJECTOR

CROSS-REFERENCE TO RELATED APPLICATION

This application is based on Japanese Patent Application No. 2014-38468 filed on Feb. 28, 2014, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a fuel injector that injects a fuel into a cylinder of an internal combustion engine.

BACKGROUND

JP2006-510849A (U.S.2006-0226263A1, DE10325289A1, CN1798920A) discloses a fuel injector, in particular for a direct injection of fuel into a combustion chamber of an internal combustion engine. The fuel injector has a valve-closure member which cooperates with a valve-seat surface formed on a valve-seat body, to form a sealing seat. The fuel injector includes at least one spray-discharge orifice provided downstream from the sealing seat. The spray-discharge orifice has a guide region and an exit region arranged at its discharge-side end. The exit region widens in a stepped manner by at least one first step and/or at least in part continuously beginning with a transition from the guide region into the exit region. A fuel jet which emerges from the guide region at the transition and widens essentially uniformly at a jet angle, passes a discharge-side end of the exit region with a gap dimension of a gap after a distance. The gap dimension is greater than zero and a first volume remaining in the exit region between the fuel jet and the inner walls of the exit region.

In the conventional fuel injector, when a pressure of a fuel spray is lower than a specified value, the fuel spray is formed to suppress a caulking. However, when a pressure of a fuel spray is higher than the specified value, the fuel spray is attracted to an inner wall surface of the injector body. The fuel may adhere to the inner wall surface.

SUMMARY

It is an object of the present disclosure to provide a fuel injector capable of suppressing a caulking and an instability of a fuel spray shape.

According to the present disclosure, a fuel injector has a cylindrical nozzle body, a nozzle needle axially moving in the cylindrical nozzle body, a pressure chamber defined between the nozzle needle and the cylindrical nozzle body for receiving a fuel therein, and an injection passage defined in the nozzle body to fluidly connect the pressure chamber and a cylinder of an internal combustion engine. The fuel in the pressure chamber is injected into the cylinder as a fuel spray. The injection passage has a first hole which is opened to the pressure chamber and a second hole which is opened to the cylinder. An inner diameter of the second hole is larger than an inner diameter of the first hole. An outer periphery line of the fuel spray agrees with an inner wall of the second hole at a contact point. A minimum vertical distance between an outer periphery of a first nozzle hole outlet and the contact point relative to an axial center line of the first hole is defined as a vertical distance R. A minimum axial distance between the first nozzle hole outlet and the contact point relative to an axial center line of the first hole is defined as an axial distance L. An angle between the axial center line of the first nozzle hole and the outer periphery line of the fuel spray is defined as an injection angle θ. The vertical distance R, the axial distance L and the injection angle θ satisfy a formula: $R/(L \times \tan\theta) > 6.0$.

According to the present disclosure, a caulking and an instability of a fuel spray can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1** is a longitudinal-sectional view showing a fuel injector according to a first embodiment;

FIG. **2** is an enlarged sectional view showing a tip end portion of the fuel injector according to the first embodiment;

FIG. **3** is an enlarged sectional view schematically showing an injection passage according to the first embodiment;

FIG. **4** is a diagram showing experimental results;

FIG. **5** is a graph showing a correlation between an injection angle θ and a characteristic value X;

FIG. **6** is an enlarged sectional view schematically showing an injection passage according to a second embodiment;

FIG. **7** is an enlarged sectional view schematically showing an injection passage according to a third embodiment;

FIG. **8** is an enlarged sectional view schematically showing an injection passage according to a first modification; and

FIG. **9** is an enlarged sectional view schematically showing an injection passage according to a second modification.

DETAILED DESCRIPTION

Hereafter, embodiments of the present disclosure will be described hereinafter. In each embodiment, the same parts and the components are indicated with the same reference numeral and the same description will not be reiterated.

First Embodiment

Referring to FIG. **1** to FIG. **4**, a fuel injector **1** of the first embodiment will be explained, hereinafter.

The fuel injector **1** has a nozzle body **2**, a nozzle needle **3**, and a pressure control portion **10**. The pressure control portion **10** controls a pressure in a pressure chamber **5** defined between the nozzle body **2** and the nozzle needle **3**, whereby the nozzle needle **3** moves up and down.

The nozzle body **2** is cylindrically shaped and is made of ferrous materials. The nozzle body **2** defines a space therein. The nozzle needle **3** is accommodated in the space. The pressure chamber **5** is defined between the nozzle needle **3** and the nozzle body **2**. The pressure control portion is arranged at a base end of the nozzle body **2**. A sack portion **21** is formed at a tip end of the nozzle body **2**. The sack portion **21** has an injection passage **4** which communicates the pressure chamber **5** and a combustion chamber (not shown) of an internal combustion engine. The nozzle body **2** has a seat portion **21** with which the nozzle needle **3** is brought into contact.

The nozzle needle **3** is a column which has three recesses **31** on its outer surface. Each of the recesses **31** extends in an axial direction of the nozzle needle **3**. The fuel flows from the bottom end to the tip end of the nozzle body **2** through the recesses **31**. The nozzle needle **3** has an annular shim **6**. A cylinder **11** of the pressure control portion **10** is provided to the base end of the nozzle needle **3**. A first spring **71** is disposed between the shim **6** and the cylinder in such a manner as to bias the nozzle needle **3** toward its tip end.

The pressure control portion **10** includes the cylinder **11**, an orifice plate **8** and a second spring **72**. The base end of the nozzle needle **3** and the orifice plate **8** are arranged inside of the cylinder **11**. The orifice plate **8** has an orifice **81**. The orifice **81** communicates with a fuel passage extending from a common-rail (not shown). A fuel quantity passing through the orifice **81** is adjusted by an electromagnetic valve provided in the fuel passage.

The second spring **72** is disposed between the orifice plate **8** and the nozzle needle **3**. The second spring **72** biases the orifice plate **8** toward the base end of the nozzle body **2**. Moreover, a control chamber **9** is defined between the cylinder **11**, the orifice plate **8** and the nozzle needle **3**. The fuel is introduced into the control chamber **9** through the orifice **81**. The pressure in the control chamber **9** is controlled by adjusting the fuel quantity by the electromagnetic valve.

When the fuel is less introduced into the control chamber **9**, the pressure in the control chamber **9** is decreased. The nozzle needle **3** receives a fuel pressure in the pressure chamber **5**, whereby the nozzle needle **3** moves apart from the seat portion **21**. Meanwhile, when the fuel flows into the control chamber **9**, the pressure in the control chamber **9** is increased. The nozzle needle **3** receives the fuel pressure in the pressure chamber **5** and the fuel pressure in the control chamber **9**, which are substantially equal to each other. The nozzle needle **3** receives the biasing force from the first spring **71** and the second spring **72**, so that the nozzle needle **3** is brought into contact with the seat portion **21**. As above, an axial position of the nozzle needle **3** is controlled by the pressure control portion **10**. According to the position of the nozzle needle **3**, the pressure chamber **5** and the injection passage **4** are fluidly connected or disconnected with each other.

The pressure chamber **5** is formed between the nozzle body **2** and the nozzle needle **3**. The pressure chamber **5** communicates with an interior of the sack portion **21**. The fuel flows into the pressure chamber **5** from the fuel-passage-inlet **51**. The fuel-passage-inlet **51** is fluidly connected with the common-rail (not shown). The supplied fuel flows from the fuel-passage-inlet **51** toward the pressure chamber **5** through the recesses **31**. When the nozzle needle **3** moves apart from the seat portion **21**, the fuel flows into the interior of the sack portion **21**. Then, the fuel is injected into the combustion chamber through the injection passage **4**.

Referring to FIGS. **2** and **3**, the configuration of the injection passage **4** will be described in detail. FIG. **3** is a schematic chart explaining the injection passage **4**. The nozzle body **2** has a plurality of injection passages **4** at its tip end. The injection passages **4** are arranged at regular intervals around a center line of the nozzle body **2**. Thus, the fuel in the sack portion **21** can be injected into the combustion chamber uniformly. Each of the injection passages **4** is formed independently mutually. That is, each injection passage **4** does not interfere with other injection passages **4**.

The injection passage **4** is configured by a counterbore **42** and a nozzle hole **41**. The counterbore **42** is a circular concaved portion formed on the outer surface of the sack portion **21**. A diameter of the counterbore **42** is larger than that of the nozzle hole **41**. Thus, a stepped surface is formed in the injection passage **4** between the counterbore **42** and the nozzle hole **41**. One end of the nozzle hole **41** is opened to the interior of the sack portion **21** and the other end of the nozzle hole **41** is opened to the counterbore **42**. The counterbore **42** and the interior of the sack portion **21** are fluidly connected with each other through the nozzle hole **41**. The nozzle hole **41** has a circular cross section. Moreover, an axial center line AX**2** of the counterbore **42** and an axial center line AX**1** of the nozzle hole **41** are coincide with each other. The diameter of the nozzle hole **41** is smaller than that of the counterbore **42**. The nozzle hole **41** corresponds to a first hole and the counterbore **42** corresponds to a second hole.

The nozzle hole **41** has a constant diameter from a nozzle hole inlet **411** to a nozzle hole outlet **412**. The fuel can flow in the nozzle hole **41** smoothly.

The fuel passed through the nozzle hole **41** is spread in the counterbore **42** by its own pressure. The spread fuel is referred to a fuel spray, hereinafter.

The fuel spray has a specified injection angle θ**1** in the counterbore **42**. As shown in FIG. **3**, the injection angle is defined between the axial center line AX**2** of the nozzle hole **41** and an outer periphery line Se**1** of the fuel spray. The injection angle θ**1** varies according to an injection pressure and an axial length of the nozzle hole **41**. As the injection angle θ**1** becomes larger, the outer periphery line Se**1** of the fuel spray comes more close to an inner wall **422** of the counterbore **42**. When the fuel spray is most spread, the outer periphery line Se**1** of the fuel spray agrees with the inner wall **422** of the counterbore **42** at a contact point **423**.

A vertical distance "R" relative to the axial center line AX**1** is a minimum distance between an outer periphery **413** of the nozzle hole outlet **412** and the contact point **423**. An axial distance "L" relative to the axial center line AX**1** is a minimum distance between the nozzle hole outlet **412** and the contact point **423**. The nozzle hole **41** and the counterbore **42** are formed in such a manner as to satisfy a following formula:

$$R/(L\times\tan\theta 1)>6.0$$

Especially, regarding the fuel injector **1** for a diesel engine, the fuel is pressurized to 25 Mpa-250 Mpa, whereby the injection angle θ**1** tends to become larger. According to the present embodiment, even if the fuel is injected under the pressure of 25 MPa-250 Mpa, the above formula is satisfied.

Referring to FIG. **3**, an advantage and an operation of the fuel injector **1** of the first embodiment will be explained, hereinafter.

Generally, as the fuel injection pressure becomes higher, a spreading force of the fuel spray becomes greater. Thus, the injection angle θ**1** also becomes larger. A distance between the outer periphery line Se**1** and the contact point **423** become shorter.

When the distance between the outer periphery line Se**1** and the contact point **423** becomes short, the Coanda effect is generated between the fuel spray and the inner wall **422** of the counterbore **42**. The fuel spray is attracted toward the inner wall **422** due to the Coanda effect. The shape of the fuel spray is changed. FIG. **3** shows an outer periphery line Se**2** of the fuel spray. As a distance between the outer periphery line Se**1** and the contact point **423** becomes shorter, the Coanda effect is more generated. The fuel spray is more attracted toward the contact point **423**. Since the diameter of the injection passage **4** is extremely small, the outer periphery line Se**1** is attracted to the contact point **423** due to the Coanda effect.

The Coanda effect may cause following phenomena. The fuel spray is attracted toward the inner wall **422** of the counterbore **42** and a part of the fuel spray remains in the counterbore **42**. The fuel spray is easily brought into contact with the inner wall **422** of the counterbore **42**. The counterbore **42** has a space **421** through which no fuel spray passes. A swirl of the fuel is generated in the space **421**. The swirl makes the remaining fuel spray flow out. When the remaining fuel quantity becomes larger than the flowing-out fuel quantity, a part of the fuel continues to remain in the space **421**. The fuel may adhere to the injection passage **4**, which is referred to as a caulking. When the fuel spray is attracted toward the inner wall **422** due to the Coanda effect, the shape of the fuel spray will be changed. A penetration force and an infusibility of the fuel spray changes in the combustion chamber.

In view of the above phenomena, the present inventors have found out that specific dimensions of the injection passage **4** can effectively restrict the Coanda effect. When the ratio R/L becomes less than a specified value, the Coanda effect is generated. Thus, according to the present embodiment, the ratio R/L is larger than the specified value in order to restrict the Coanda effect. A caulking in the injection passage **4** can be suppressed. An instability of a fuel-spray shape can be suppressed.

FIGS. **4** and **5** are diagrams showing results of experiments for explaining effects of the present embodiment. The experiments are conducted with respect to fuel injectors "A" to "H" having the injection passage **4** and the counterbore **42** respectively. The fuel injection pressure Pr is varied from 25 Mpa to 250 Mpa. Regarding each one of the fuel injectors "A" to "H", four experiments "Test1" to "Test 4" are conducted. As shown in FIG. **5**, each of the fuel injectors "A" to "H" has its own distances "R" and "L". In each experiment, the injection angle θ is measured to compute "R/L×tan θ". The value of the "R/L×tan θ" is referred to as a characteristic value X, hereinafter. The experiments "Test1" to "Test4" are conducted in this order. In the experiment "Test1", the fuel injection pressure Pr is lowest among the experiments. The fuel injection pressure Pr is increased along with the order of experiments "Test1" to "Test4". That is, in the experiment "Test4", the fuel injection pressure Pr is highest among the experiments.

As the fuel injection pressure Pr is higher, the injection angle θ becomes larger. However, the injection angle θ in "Test3" is smaller than that in "Test2" with respect to the fuel injectors "A", "B", "D", and "G". With respect to the fuel injectors "A", "C" and "D", there is no caulking in each experiment "Test1" to "Test4". On the other hand, with respect to the fuel injectors "G" and "H", there is a caulking in each experiment "Test1" to "Test4". With respect to the fuel injector "B", there is no caulking in "Test3" and "Test4", however, there is a caulking in "Test1" and "Test2". With respect to the fuel injectors "E" and "F", there is no caulking in "Test1" and "Test2", however, there is a caulking in "Test3".

Based on the experimental results shown in FIG. **4**, a correlation between the injection angle θ and the characteristic value X is obtained. FIG. **5** shows an approximate line Nr. When the characteristic value X is smaller than a specified value, the injection angle θ becomes large. When the characteristic value X is greater than the specified value, the injection angle θ does not become large. It is considered that the fuel spray is not attracted toward the inner wall **422** of the counterbore **42** and the Coanda effect is restricted. According to the experimental results, when the characteristic value X is greater than or equal to a threshold "Th", the Coanda effect is restricted. That is, when characteristic value X is greater than or equal to 6.0, the Coanda effect is restricted, whereby the caulking can be suppressed without making the injection angle θ large. The injection angle θ is converged to a specified angle. The shape of the fuel spray can be stabilized.

As above, the fuel injector is configured so that the characteristic value X is greater than or equal to 6.0. The Coanda effect can be suppressed. It can be avoided that the fuel adheres to the inner wall **422** of a counterbore **42**. The injection angle does not vary significantly. Thus, a caulking in the injection passage can be suppressed and an instability of a fuel-spray shape can be suppressed.

According to the present embodiment, the fuel injector **1** has the injection passage **4** which satisfies the above described formula: R/(L×tan θ**1**)>6.0

Even if the fuel pressure is high, it is restricted that the fuel spray is attracted to the inner wall **422** of the counterbore **42**. A caulking can be suppressed effectively. The fuel spray shape is stabilized and a combustion can be conducted effectively.

Furthermore, in the present embodiment, a plurality of injection passages **4** is formed in the nozzle body **2**. The counterbore **42** of each injection passage **4** is formed so that the injection passages **4** are not fluidly connected to each other. That is, each injection passage **4** does not interfere with other injection passages **4**. Thereby, it can be suppressed that the mechanical strength of the nozzle body **2** is decreased due to the counterbores **42**. Moreover, since each injection passage **4** does not interfere with other injection passages **4**, it can be suppressed that the fuel spray collides with each other. The shape of the fuel spray is not disturbed.

Furthermore, in the present embodiment, the diameter of the nozzle hole inlet **411** is equal to the diameter of the nozzle hole outlet **412**. The flow velocity of the fuel in the injection passage **4** is increased. For this reason, the fuel flow in the injection passage **4** may become a turbulent flow. However, according to the present embodiment, since the inner diameter of the nozzle hole **41** is constant, the fuel flow in the nozzle hole **41** becomes the laminar flow. The shape of the fuel spray can be stable.

The axial center line AX**1** of the counterbore **42** and the axial center line AX**2** of the nozzle hole **41** are coincide with each other. Thus, the counterbore **42** can be easily formed to satisfy the above formula.

Second Embodiment

A second embodiment will be described hereinafter. In the second embodiment, as shown in FIG. **6**, the configuration of the nozzle hole **43** is different from the first embodiment. FIG. **6** is a schematic chart explaining the injection passage **4**.

An inner diameter of the nozzle hole inlet **411** is greater than that of the nozzle hole outlet **412**. The inner diameter of the nozzle hole **43** is gradually decreased from the nozzle hole inlet **411** toward the nozzle hole outlet **412**. The vertical distance "R", the axial distance "L", the injection angle θ**2** are defined as to satisfy the following formula: R/(L×tan θ**2**)>6.

A caulking in the injection passage **4** can be suppressed. An instability of a fuel-spray shape can be suppressed.

Moreover, since the inner diameter of the nozzle hole **43** is gradually decreased from the nozzle hole inlet **411** toward the nozzle hole outlet **412**, the flow velocity of the fuel is increased in the injection passage **4**. Thereby, the penetration force of the fuel spray is increased.

Third Embodiment

A third embodiment will be described hereinafter. In the third embodiment, as shown in FIG. **7**, the configuration of the counterbore **44** is different from the first embodiment. FIG. **7** is a schematic chart explaining the injection passage **4**.

An axial center line AX**2** of the counterbore **44** deviates from an axial center line AX**1** of the nozzle hole **44**. Since the center line of the fuel spray deviates from the center line of the counterbore **44**, the outer diameter of the fuel spray is different from the inner diameter of the counterbore **44**. The contact point **423** exists on the inner wall **422** of a counterbore **44**. A caulking in the injection passage **4** can be suppressed and an instability of a fuel-spray shape can be suppressed.

Other Embodiments

The present disclosure should not be limited to the above embodiments, but may be implemented in other ways without departing from the spirit of the disclosure. FIGS. **8** and **9** are schematic charts explaining the injection passage **4**.

FIG. **8** shows a first modification in which the inner diameter of the inner wall **422** gradually increases toward the outlet of the injection passage **4**. The injection passage **4** is configures to satisfy the formula: $R/(L\times\tan\theta 4)>6.0$

FIG. **9** shows a second modification in which the injection passage **4** has three counterbores **142**, **242**, **342** of which inner diameter is different from each other. The contact point **423** exists between a first counterbore **142** and the second counterbore **242**.

The first counterbore **142** is configured to satisfy the following formula: $R/(L\times\tan\theta 5)>6.0$

Furthermore, according to a third modification, any one of the nozzle hole **41** and the counterbore **42** may be an ellipse.

What is claimed is:

1. A fuel injector comprising:

a cylindrical nozzle body;

a nozzle needle axially moving in the cylindrical nozzle body;

a pressure chamber defined between the nozzle needle and the cylindrical nozzle body for receiving a fuel therein; and

an injection passage defined in the nozzle body to fluidly connect the pressure chamber and a cylinder of an internal combustion engine, wherein

the fuel in the pressure chamber is injected into the cylinder as a fuel spray,

the injection passage has a first hole which is opened to the pressure chamber and a second hole which is opened to the cylinder,

an inner diameter of the second hole is larger than an inner diameter of the first hole,

an outer periphery line of the fuel spray agrees with an inner wall of the second hole at a contact point,

a minimum vertical distance between an outer periphery of a first nozzle hole outlet and the contact point relative to an axial center line of the first hole is defined as a vertical distance R,

a minimum axial distance between the first nozzle hole outlet and the contact point relative to an axial center line of the first hole is defined as an axial distance L,

an angle between the axial center line of the first nozzle hole and the outer periphery line of the fuel spray is defined as an injection angle θ, and

the vertical distance R, the axial distance L and the injection angle θ satisfy a formula: $R/(L\times\tan\theta)>6.0$.

2. A fuel injector according to claim **1**, wherein

a pressure Pr of the fuel in the pressure chamber satisfies 25 Mpa≤Pr≤250 MPa.

3. A fuel injector according to claim **1**, wherein

the cylindrical nozzle body has a plurality of injection passages, and

the second hole of each injection passage is not fluidly connected to other second holes.

4. A fuel injector according to claim **1**, wherein

the first hole has a nozzle hole inlet and a nozzle hole outlet, and

an inner diameter of the nozzle hole inlet is equal to an inner diameter of the nozzle hole outlet.

5. A fuel injector according to claim **1**, wherein

the first hole has a nozzle hole inlet and a nozzle hole outlet, and

an inner diameter of the nozzle hole inlet is larger than an inner diameter of the nozzle hole outlet.

6. A fuel injector according to claim **1**, wherein

the inner wall of the second hole is formed in parallel with the axial center line of the first hole.

7. A fuel injector according to claim **1**, wherein

an axial center line of the second hole deviates from the axial center line of the first hole.

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